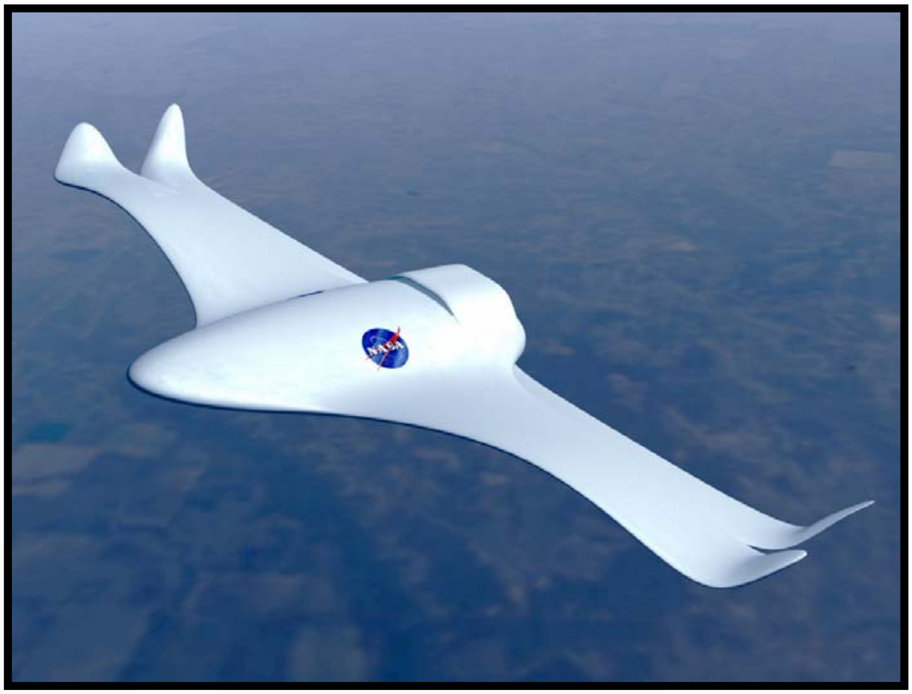
National Aeronautics and Space Administration

Can a Shoebox Fly Challenge

A Digital Learning Network Experience



A Digital Learning Network (DLN) Challenge

A DLN Challenge is an in-depth research/design experience that allows students to propose solutions to Challenge criteria and present their solutions to NASA through a videoconferencing system. The educational criteria embedded in the Challenge draws from Inquiry-based and Problem Based Learning strategies. A DLN Challenge involves more than one DLN videoconferencing connection, in-depth student involvement through research and design activities, open-ended problem solving flexibility, and formal student presentations that demonstrate understanding and application.

CAN A SHOEBOX FLY CHALLENGE

A Digital Learning Network Experience

National Aeronautics and
Space Administration

Designed To Share

NASA's Space Exploration Program

Table of Contents

Module Overview

Grade Level: 6 - 12

Focus Question:
Using your research skills and applying your knowledge of flight dynamics can you design a shoebox to glide?

Instructional Objectives:

- Students will research the dynamics and forces of flight.
- Students will apply their understanding of flight to the design, construction, and test flight of a shoebox based glider.
- Students will collect measurements and calculate glide-slope and aspect ratios.
- Students will provide a visual and oral summary of their design and test solutions.

National Standards:

Science: Science as Inquiry, Science and Technology
Mathematics: Measurement, Communication
Technology: Design,The Designed World

Texas Standards: (6.13) Science concepts, (8.5) Scientific process

Sequence of Events
Pre-Conference Requirements

Online Assessment A brief pre-assessment tool is available to determine the students' level of understanding prior to the videoconference. Suggested answers are included.

Introduction to Challenge Videoconference (About 45-60 minutes)

Join NASA in this unique design challenge and learn how to apply theoretical knowledge with design limitations to produce a working shoebox glider model. Experience the team planning and design challenges needed to carry through a design to a successful demonstration in the world of aeronautical engineering.
Video Conference outline

In-Class Research-Design Activities

Challenge criteria applied by students A problem-based learning activity that applies and extends the students' understandings in the area of flight design problems.
Solutions discovered and summarized into Student Presentation

Content and Presentation Rubric Guidelines

Presentation of Student Solutions Videoconference (About 45-60 minutes)

This conference allows selected teams to verify and demonstrate their glider’s flight and summarize the experience in a timed oral and visual presentation to NASA.

Videoconference outline

Post-Conference Requirements

Online Assessment

A post-event online assessment is available to determine changes in student levels of understanding.

NASA Education Evaluation Information System (NEISS) Feedback Forms

National Standards

National Science Education Standards (NSES)

Science as Inquiry – Content Standard A

As a result of activities in grades 5-8 and 9-12, all students should develop:

- Abilities necessary to do scientific inquiry.
- Understandings about scientific inquiry.

Science and Technology – Content Standard E

As a result of activities in grades 5-8 and 9-12, all students should develop:

- Abilities of technological design.
- Understandings about science and technology.

National Council of Teachers of Mathematics (NCTM)

Standard 4 – Measurement

In all grades students should:

- Apply a variety of techniques, tools, and formulas for determining measurement.

Standard 8 – Communication

In all grades students should:

- Organize and consolidate their mathematical thinking to communicate with others.
- Express mathematical ideas coherently and clearly to peers, teachers, and others.

International Technology Education Association (ITEA)

Design – Standard 10

- Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving

The Designed World – Standard 17

- Students will develop an understanding of and be able to select and use information and communication technologies.

Texas Standards

(6.5) Scientific concepts. The student knows that systems may combine with other systems to form a larger system.

(A) identify and describe a system that results from the combination of two or more systems such as in the solar system; and
(B) describe how the properties of a system are different from the properties of its parts.

(8.5) Scientific processes. The student knows that relationships exist between science and technology.
(A) identify a design problem and propose a solution;
(B) design and test a model to solve the problem; and
(C) evaluate the model and make recommendations for improving the model.

Pre-investigation Requirements

Pre-Assessment

A week before the event, students will need to take this pre-conference assessment. This short assessment will provide useful background information for the presenters to prepare for the videoconference.

Pre-Conference Assessment Questions

1. Name the forces experienced by a glider in flight?

2. What major design issues need to be considered for any flying machine?

3. What forces affect all things that fly?

4. Can you name at least three careers in aviation?

5. What is a ratio?

6. What does a glide slope ratio indicate?

7. Which ratio indicates the best glide slope?
   a. 8:4
   b. 10:5
   c. 4:1

8. Which glide slope ratio indicated that a glider never flew?
   a. 1:2
   b. 0:5
   c. 10:1

9. What does the aspect ratio measure?

10. Is there a relationship between glide slope and aspect ratios?

11. What is an airfoil?

Answers to Pre and Post Assessment Questions

1. A glider uses thrust, drag, lift, and gravity (weight) during flight.

2. Aerodynamics, Stress, and Weight.

3. Lift, drag, thrust, and weight (gravity) affect all things that fly.

4. Pilot, Flight Instructor, Astronaut, Mechanic, Airport Manager, Flight Dispatcher, Safety Inspector, Aircraft Designer, Air Traffic Controller, Flight Attendant, Engineers, Meteorologist

Pilot	Flight Instructor	Astronaut
Mechanic	Airport Manager	Flight Dispatcher
Safety Inspector	Aircraft Designer	Air Traffic Controller
Flight Attendant	Engineers	Meteorologist

5. A ratio is a comparison of two quantities by division. The quantities are called the terms of the ratio.

6. The relationship between horizontal distance and a change in altitude, or the rate of decent.

7. Answer c. 4:1

8. Answer b. 0:5

9. The relationship between the length of the wing divided by its width (measured from the leading edge of the wing to the trailing edge or its cord).

10. Answers will vary. Students should analyze the combined class data of all glide slope and aspect ratios to make a determination.

11. An airfoil is any surface that provides aerodynamic force when it interacts with a moving stream of air. On an airplane, airfoil refers to the wing.

Introduction to Challenge Videoconference Outline

Introduction to Challenge Videoconference

Join NASA and its flight engineers in this unique design challenge. Learn how to apply theoretical knowledge with design limitations to produce a working glider model. Experience the team planning and design challenges needed to carry through a design concept to a successful demonstration in the world of aeronautical engineering.

Introduction to the Challenge Outline

- Introduction to NASA
- Today's objectives
- Historical look at Experimental Aircraft and Flight
- Building Engineering Teams
- Aircraft Design Needs
- Developing a Principle of Lift
- Looking at Forces of Flight
- Glide Slope and Aspect Ratios
- Stating the Challenge, criteria and constraints
- Clarification: Student questions, resources, research
- Student presentation expectations
- How to stay in contact
- Good bye to Chase the Problem…as only NASA can!

In-Class Research-Design Activities

RISKING FAILURE TO BE SUCCESSFUL
CHASE THE PROBLEM
TO MEET THE CHALLENGE
TO FLY THE DREAM

Here is your Challenge:

Produce a design that incorporates a shoebox as part of your glider. Additionally your Shoebox Glider will have to meet the criteria and constraints partially listed below.
Your Challenge is open-ended and involves a variety of collaborative and creative problem solving efforts!

As part of your challenge, you will need to accomplish the following tasks:

- Research the dynamics of flight and apply them to your efforts.
- Determine and gather the materials you will need for your glider.
- Determine how to launch the shoebox glider in a consistent way.
- Obtain the most efficient glide slope ratio possible.
- Demonstrate your understanding and success to NASA

Guidelines

1. Write the words “criteria and constraints” on the board. Ask students to define the terms. Explain that when designing any device, the inventor-engineer must consider criteria and constraints.
   *The students should understand that **criteria** are standards or requirements that the device must include. Examples of criteria are that the device must be efficient, must be able to land gently, and must be able to glide a certain distance.*
   ***Constraints** are things that limit the design of the glider. Examples of constraints are money, time, maximum size, available materials, space to build or fly, and human capabilities.*

2. Under the title: “Shoebox Glider Criteria” write the following:
   a. The glider must move forward for at least 3 meters.
   b. The glider must demonstrate an efficient positive glide slope ratio.
   c. The glider must not break upon landing.
   d. The glider’s glide slope and aspect ratios must be determined.
   e. Teams will prepare a final presentation of results and understanding based on the scoring rubric.

3. Under the title: “Shoebox Glider Constraints” write the following:
   a. The glider must include an intact shoebox in its design.

   b. There are no material constraints.
   c. There will be a working-researching-testing time limit set by the classroom teacher.
   d. Final team presentations will be limited by time, depending on the number of total presentations. Usually 5 to 6 minutes.
4. Using provided and any additional resources students can begin background research, gathering materials, designing, and construction.

Peer Evaluations

1. After student teams have completed their research and designs, have different groups switch design plans and evaluate each other's proposals.
2. In this evaluation process, the groups should focus on whether the design meets the criteria and constraints up to this point and to offer any constructive criticisms or suggestions that would lead to greater success.
3. Once the groups have shared their evaluations, discuss as a class what the students learned from this peer evaluation. Lead a discussion using the following questions:
   a. Did your glider design meet the criteria and constraints?
   b. What changes would you make and why?
   c. What helpful comments did you get from the other group?
4. Explain to the students that an important part of the design process is revising the designs prior and during flight-testing.

Preparing for Flight Tests

1. After making improvements, the teams should be ready to test their shoebox gliders. *Note to teacher: A large space will be needed where the gliders can be tested. Outside or in your school's gym might be a great place to test them.*
2. Have teams keep records of designs, research, peer evaluations, changes made, what problems they had to solve during the design process and how they solved those problems.
3. Based on the scoring rubric have the students be responsible for gathering and recording the following data: how high the glider was released from (altitude), the distance it covered, calculating glide slope and graphing these results, determining the glider's aspect ratio, and total time aloft.

Flight Testing

1. Explain that the teams are now going to compete against each other to determine which glider is the most efficient in terms of glide slope. A glide slope is a method of making a standardized comparison of each team's efforts regardless of the height a team's glider was released from or the distance it covered. Discuss that there is not a perfect design, but scientists and engineers do look for the design that is the most efficient.
2. Discuss with the students that sometimes tradeoffs have to be made among features (aerodynamics, stress, and weight) in order to make the

glider the most efficient. Ask students to identify and record any tradeoffs that they make to their gliders during their flight tests.

3. Have teams run as many flight tests as possible during the time constraints set by the classroom teacher. The data from the test flights can then be averaged, or the best one used.
4. Have the students compare the data of their original test flight to their later or best flight to monitor improvements in efficiency.
5. As a class, decide which gliders are the most efficient in terms of the glide slope data obtained from their flight tests. Discuss with the students that this does not mean this is the perfect design.

Discussion/Wrap-up and Team Presentations

1. Have the students explain the steps they went through to design their shoebox gliders. Ask the students if they think scientists and engineers follow similar steps. After the students have shared their ideas, explain that the students followed a very similar process to that of design engineers.
2. Explain that the basic design process includes: defining a problem, specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or building it, and communicating the process and results to others.
3. Using the scoring rubrics for “PowerPoint Visual Design” and “Final Student Presentation” as a guide select the best student teams to prepare a 5 to 6 minute visual-oral presentation for NASA of their flight test results, understanding of flight dynamics, and problem solving process.

The Glide Slope Ratio

Glide Slope is a number that indicates how well your designed shoebox glider flies through the air in terms of its forward distance vs. its drop in altitude.
Glide Ratio = Horizontal Distance divided by the Change in Altitude.
Another way to think of this is to ask, how far did the glider travel forward for every foot it dropped in altitude?

For example: You released your Shoebox Glider from atop a 10-foot high ladder. Your glider traveled 50 feet before landing on the floor.
Horizontal Distance = 50 feet
Change in Altitude   = 10 feet
Dividing Distance (50) by Altitude (10) = 5   The Glide Ratio is 5
50/10 = 5/1 = 5 The glider flew forward 5 feet for every 1-foot drop in altitude.

Further explanation and graphed examples of Glide Slope Ratios and their interpretations are located under ‘Background Information’ on page

Content and Presentation Rubric

Student Team Presentations

Student teams are selected to present to NASA's DLN

- Classroom Teachers and NASA Educational Host, along with Rubric results, can be used to determine which student teams will present their results during the second DLN connection.
- The remaining student teams will be passive participants.

Student Presentation Requirements

- Each team has 5 to 6 minutes to present the following items and information:
  - The actual experimental Shoebox Glider
  - Visual of its flight (images in sequence, video, MPEG, etc.)
  - Recorded Distance and Height of flight
  - Calculated Glide Slope = D/H
  - Calculated Aspect Ratio = L/W
  - Interpretation of Glide Slope w/ graph of slope
  - Interpretation of any relationships between Glide Slope and Aspect Ratios
  - Description of problems and successes during design process.

A. Glide Slope – Aspect Ratios Calculated and Explained

TOPIC	POSSIBLE POINTS	EARNED POINTS	COMMENTS
Height & Distance Recorded	5		
Glide Slope Calculated	5		
Glide Slope Explained	10		
Glide Slope Graphed	10		
Aspect Ratio Determined	5		
Aspect Ratio Explained	5		
Glide Slope vs. Aspect Ratio Relationship	10		
Subtotal	**50**		

B. PowerPoint Visual Design and Content

TOPIC	POSSIBLE POINTS	EARNED POINTS	COMMENTS
Readability – size of fonts, color in back/foreground	10		
Visual Support – images, graphs, charts, flight	10		
Documentation – construction, team members, and flight	10		
Concepts explained Glide Slope, Aspect, Bernoulli's, and Four Forces	10		
Graphic Design – clutter, clarity, and visual appeal	10		
Subtotal	**50**		

C. Final Student Presentation and Content

TOPIC	POSSIBLE POINTS	EARNED POINTS	COMMENTS
Visual Support – PowerPoint, Video/MPEG Graphs/Charts Shoebox Glider	20		
Voice Projection- Volume-speed Articulation Lack of filler words (um, uh)	10		
Speaker Stance- Look at audience Enthusiasm Confidence	10		
Body Gestures – Appropriate to presentation	10		
Content – Actual Glider Visual of flight Distance-Height Glide Slope Interpret slope Explain concepts Problem-success	50		
Time Set by NASA Host – Usually 4-6 min.	-0		Penalty, if any, is set by classroom teacher
Subtotal	**100**		

D.Total Score for Calculations, Webpage, Presentation

SECTION-TOPIC	POSSIBLE POINTS	EARNED POINTS	COMMENTS
A. Glide Slope	50		
B. PowerPoint	50		
C. Student Present	100		
FORMULA Add A+B+C and divide by 2 for final score	200/2=100%	%	

Presentation of Student Solutions Videoconference Outline

Student Challenge Presentation Videoconference

Student teams with the most efficient glide slope ratios will have the opportunity to make a 5 to 6 minute visual-oral presentation to NASA's Digital Learning Network team of their flight test results, understanding of flight dynamics, and problem solving process.

Presentation of Student Solutions Videoconference Outline

- Introduction to NASA and Host-Panel
- Challenge Objectives
- Team Presentation Requirements
- Timed Team Presentations with Follow up by NASA DLN host
- Closing observations and comments
- Good-bye from NASA DLN

Post-Conference

Online Post-Assessment

After the event students will need to take the online post-conference assessment. (These questions are the same questions used in the pre-assessment.) The short assessment will help us measure student learning and identify any changes that need to be made in future programs.

Pre-Conference Assessment Questions

1. Name the forces experienced by a glider in flight?
2. What major design issues need to be considered for any flying machine?
3. What forces affect all things that fly?
4. Can you name at least three careers in aviation?
5. What is a ratio?
6. What does a glide slope ratio indicate?
7. Which ratio indicates the best glide slope?
   a. 8:4
   b. 10:5
   c. 4:1
8. Which glide slope ratio indicated that a glider never flew?
   a. 1:2
   b. 5:0
   c. 10:1
9. What does the aspect ratio measure?
10. Is there a relationship between glide slope and aspect ratios?
11. What is an airfoil?

Digital Learning Network

Certificate of Completion

This certifies that

Has completed NASA's
Shoebox Glider Challenge

Instructor

NASA Education Evaluation Information System (NEEIS) Feedback Forms

Please complete an online evaluation form to provide feedback on the NASA Challenge. ***Feedback from you and a few of your students would be appreciated.***

http://dln.nasa.gov/dln/content/feedback/

Vocabulary

Airfoil – parts of an airplane, such as wings, tail surfaces, and propellers, designed to cause a dynamic reaction from the air through which it moves.
Aeronautics – the science and art of flight through the atmosphere.
Aspect Ratio – the length of a wing divided by the width (cord).
Aerodynamics – the branch of mechanics dealing with forces exerted by air or other gases in motion.
Angle of Attack – the angle created by the pilot during takeoff, the angle between the chord line and the oncoming relative wind.
Bernoulli's Principle – states, "as a fluid's speed increases, the pressure within the fluid decreases." So the pressure on top of an airfoil must be less than the pressure below.
Cambered – curved upper surface on a wing to increase lift.
Chord – (airfoil) an imaginary line that connects the leading edge with the trailing edge of the airfoil.
Drag – a slowing force acting on a body (as an airfoil or airplane) moving through air, parallel and opposite to the direction of motion.
Force – the cause of motion. Power or energy exerted against an object in a given direction.
Fuselage – the basic structure of the airplane to which all the other parts are attached.
Glide Slope Ratio – the horizontal distance divided by the change in altitude.
Gravity – the term used to describe the force of attraction that exists between all matter within the universe.
Lift – the upward force that opposes the pull of gravity.
Lateral axis – an imaginary line that runs from one wingtip through the fuselage and exits the other wingtip. Also called the pitch axis.
Leading edge (airfoil) – the edge that meets relative wind first.
Mass – the amount of material in an object.
Relative wind – opposite the flight path and impacts the airfoil at any angle to the chord line.
Stall – separation between the streamlines and the airfoil causing loss of lift producing low-pressure on the top of the wing.
Thrust – the force exerted through the propeller shaft of an airplane due to reaction of the air on the revolving blades of the propeller and that moves the craft ahead.
Trailing edge (airfoil) – the thin junction where the upper and lower surfaces come together at the rear of the wing.
Weight – force that directly opposes lift.
Wing – primary source of lift with ailerons attached.

Resources

The Beginners Guide to Aerodynamics (Grade 6-12)
How do airplanes work? Why does a wing change shape on takeoff and landing? Start your journey into aerodynamics.
http://www.grc.nasa.gov/WWW/K-12/airplane/bga.html

FoilSim (Grades 6-12)
FoilSim was developed at the NASA Glenn Research Center in an effort to foster hands-on, inquiry-based learning in science and math. FoilSim is interactive simulation software that determines the airflow around various shapes of airfoils.
http://www.grc.nasa.gov/WWW/K-12/FoilSim/index.html

X-1 Paper Glider Kit (Grades 5-12)
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/X1.Paper.Glider.Kit.html

Space Shuttle Glider (Grades 5-12)
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Space.Shuttle.Glider.html

NASA Event Guidelines

1. Audience Guidelines

Educators, please review the following points with your students prior to the event:

- Videoconference is a two-way event. Students and NASA presenters can see and hear one another.
- Students are sometimes initially shy about responding to questions during a distance learning session. Explain to the students that this is an interactive medium and we encourage questions.
- Students should speak in a loud, clear voice. If a microphone is placed in a central location, instruct the students to walk up and speak into the microphone.
- Educator(s) should moderate students' questions and answers.
- Students should remain quiet while others are talking. The microphones pick up background noise, and this can be very distracting.
- Students are representing their school; they should be on their best behavior.
- Students should be prepared to give brief presentations (depending upon challenge selected), ask questions, and respond to NASA presenters.

2. Educator Event Checklists

Date Completed	Introduction to Challenge Pre-Conference Requirements
	1. Print a copy of the challenge.
	2. Have the students complete the online pre-assessment.
	3. Email questions for the presenter. This will help focus the presentation on the groups' specific needs.
	4. Review the Audience Guidelines, which can be found in the previous section.
	Day of the Event Requirements
	2. The students are encouraged to ask the NASA presenter qualifying questions about the Challenge.
	3. Follow up questions can be continued after the conference through e-mail.
	Introduction to Challenge Post-Conference Requirements
	1. Have the students begin their research, construction, and testing phases of the Challenge.
	2. Use the provided rubric as guidelines for content and presentation criteria.
	3. Students can continue to e-mail questions to the NASA presenters about the Challenge and its criteria as they arise.

Date Completed	Presentation of Student Solutions Pre-Conference Requirements
	1. Review the Audience Guidelines, which can be found in the previous section.
	2. Students may use the content and presentation rubric as guidelines for final presentations to the NASA presenters.
	3. Students should have their final solutions prepared for a timed formal presentation.
	5. Using a variety of presentation methods (oral, visual, PowerPoint, mpeg, video, charts, etc) students should practice and time their presentations.
	Day of the Event Requirements
	4. The students will be asked to share their results from their pre-conference lesson with the NASA presenters.
	5. Bring any materials to help support the student presentations.
	Presentation of Student Solutions Post-Conference Requirements
	4. Have the students take the online Post-Assessment to demonstrate their knowledge of the subject.
	5. Educator(s) and students fill out the event feedback.

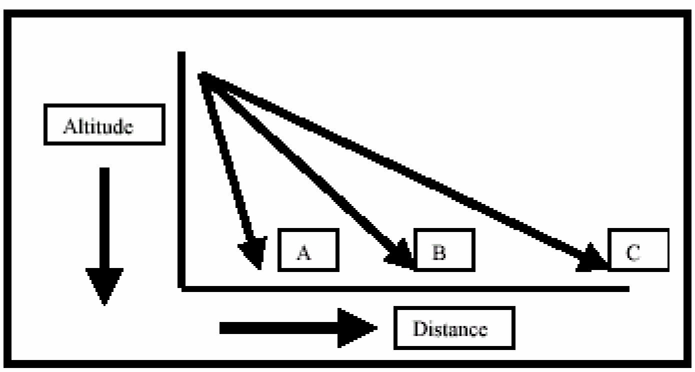
Background Information

The Glide Slope Ratio is a number that indicates how well your designed shoebox glider flies through the air in terms of its forward distance vs. its drop in altitude.
Glide Ratio = Horizontal Distance divided by the Change in Altitude.
Another way to think of this is to ask, how far did the glider travel forward for every foot it dropped in altitude?

For example: You released your Shoebox Glider from atop a 10-foot high ladder. Your glider traveled 50 feet before landing on the floor.

Horizontal Distance = 50 feet
Change in Altitude = 10 feet
Dividing Distance (50) by Altitude (10) = 5 The Glide Ratio is 5
50/10 = 5/1 = 5 The glider flew forward 5 feet for every 1-foot drop in altitude.

Graphed examples of Glide Slope Ratios and their interpretations:



Glide Slope "A" would represent a good Glide-Slope Ratio
Distance = 20 ft. Altitude = 10 ft.
Distance (20) divided by Altitude (10) = 2/1 = Glide Ratio of 2.0
The glider flew forward two feet for every one-foot drop in altitude.

Glide Slope "B" would represent a better Glide-Slope Ratio
Distance = 50 ft. Altitude = 10 ft.
50 divided by 10 = 5/1 = Glide Ratio of 5.0
The glider flew forward five feet for every one-foot drop in altitude

Glide Slope "C" would represent the best Glide-Slope Ratio
Distance = 100 ft. Altitude = 10 ft.
100 divided by 10 = 10/1 = Glide Ratio of 10.0
The glider flew forward 10 feet for every one-foot drop in altitude!

Developing and Understanding a Principle of Lift

After each demonstration, small groups of students will work the activity until each group can duplicate the same results as originally demonstrated by their teacher.

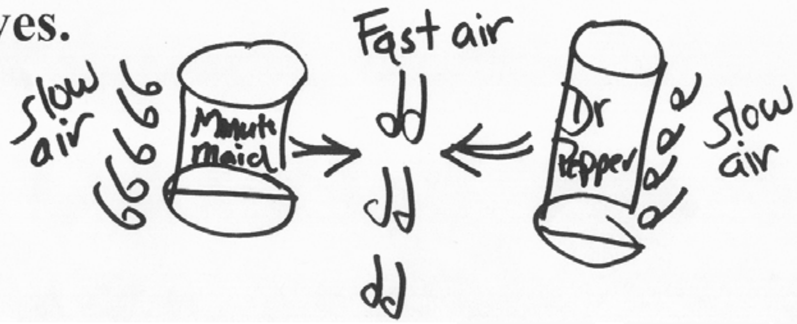
Each small group will write a description (after each demonstration) of what was observed and why they think the objects reacted the way they did when subjected to fast and slow moving air around the objects. They are to include a labeled illustration that indicates the flow of fast and slow moving air around each object (faster moving air equaling low pressure and slower moving air equaling high pressure).

After all the demonstrations have been given and each group has written their observations, explanations, and illustrations a final summary statement (principle) with a selected labeled illustration is to be written. This Principle should be written in a general, broad way to summarize how any object subjected to imbalanced flows of fast (low pressure) and slow (high pressure) moving air will behave.

An example of a Student's Principle of Flight is shown below:

Natalie's Principle

The slow air moves the object toward the fast air and the object moves. The high pressure moves the object toward the low pressure and the object then moves.



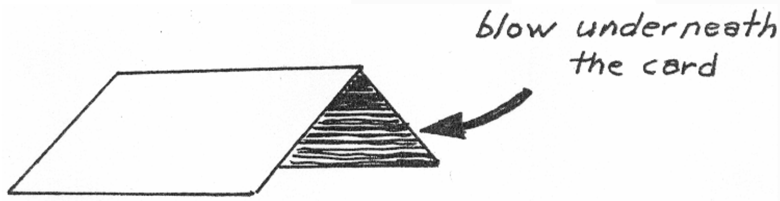
The following Discrepant Event activities will help students understand Bernoulli's Principle by writing their own Principle of Lift.
Each activity has a list of required materials.

Developing and Writing a 'Principle of Lift'

The Collapsible Paper Tent

Materials Required:

1. A pen or pencil and paper
2. 3 x 5 inch note card for each student



Procedure:

1. Distribute the note cards to each student.
2. Fold the cards in the center to form a tent structure.
3. Place the folded tent note card on a desk or table and try to blow the card off the desk or table by blowing underneath it.
4. Predict what will happen before you blow under the folded tent note card.
5. Make a sketch of what was observed. Use thick arrows to indicate stationary (or slower moving) air, thinner arrows for faster moving air, and a line arrow to indicate the motion of the paper strip.

Questions:

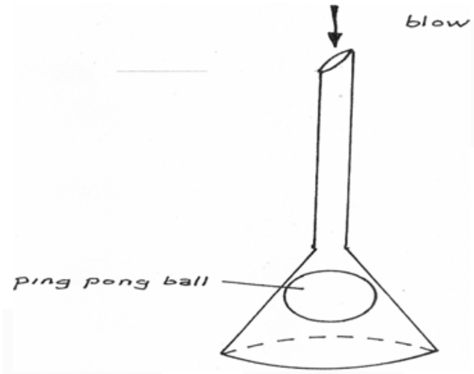
1. What did you observe when blowing underneath the paper tent? Describe the movement of the paper tent.
2. Stationary air exerts equal amounts of pressure on all sides of an object. What is different about the air on top of the paper compared to the air under the paper, when you blew underneath the paper tent?
3. What is different about the flowing air compared to the stationary air?

Explanations:
Stationary air exerts pressure. Flowing air exerts less pressure as compared to stationary air. The faster the flow, the lower the pressure it exerts. By blowing underneath the card, you actually created less pressure underneath the paper, so that the pressure above the paper became larger than below the paper, and this is why the card got pressed down against the table.

The Stubborn Ball and Its Funnel

Materials Required:

1. Pen and Pencil and paper.
2. One long-stem funnel (glass or plastic) per small group of students.
3. One ping-pong ball per small group of students.



Procedure:

1. Place the funnel and ball next to each other on a table.
2. Ask the question: "How can I pick up the ball with the funnel without sucking through the funnel? And I may not touch the ball."
3. Pick up the funnel by the stem; place it over the ball and blow steadily through the stem, lifting the funnel while blowing.
4. Place one hand under the funnel and stop blowing. The ball then drops.
5. Place the ball in the funnel and have a student try to blow the ball out of the funnel. They will not succeed.

Question:

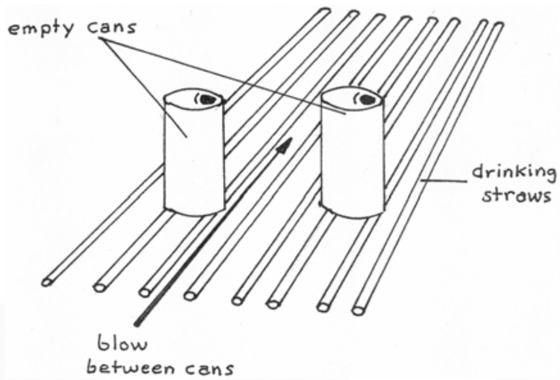
1. How did we pick up the ball with the funnel without sucking through it?
2. What happened when we stopped blowing?
3. Is it possible to blow the ball out of the funnel?
4. Where is the air moving the fastest when we blow through the funnel?
5. What is flowing (faster moving) air creating that stationary air doesn't?
6. What is the difference about the inside compared to the outside of the funnel when we blow through it?

Explanation:

The ball can be picked up from the table with the funnel by blowing through it. When blowing through the funnel we create a lower pressure inside the funnel, especially at the spot where the stem is attached to the conical shape of the funnel. Here the fastest flow of air occurs because the air molecules have suddenly more space to move about. The faster the flow of air, the lower the pressure. This is why the ball is sucked into the funnel by blowing, and for the same reason it is not possible to blow the ball out of the funnel. The harder we blow through the funnel, the lower the pressure gets in the mouth of the funnel.

The Attracting Soda Cans

Materials:
1. Pen or Pencil and Paper.
2. Two empty soda cans per small group.
3. About one dozen straight drinking straws per small group.



Procedure:
1. Spread the straws parallel to each other on the table and spread them out with about 1cm between them.
2. Place the two empty cans upright about 2 cm from each other on the straws and show the students that they can easily move on top of the cans. The straws are used to reduce friction between the tabletop and the cans.
3. Ask the students: “What can possibly happen to the cans if I blow in between them?”
4. Now spread the two cans about 5 cm apart. Will I have to blow softer or harder to get the two cans to come together? Blow harder.
5. Now place the cans about 20 cm apart. Ask the students: “Can I still get the two cans to come together?” Take a deep breath and blow a constant stream of air on the right side of the left can and move your head towards the right, while constantly blowing. The cans will still come together.

Questions:
1. What made the cans mover closer together?
2. How far apart could the cans be placed and still move together?
3. What does the flowing air create in between the two cans?
4. Was a stronger flow of air necessary to bring the cans that were 20 cm from each other?

Explanation:
Blowing in between the two cans created a flow of air and thus a lower pressure compared to the stationary air on the other side of the cans. It is this lower pressure created on one side of the can that allowed the higher pressure on the opposite side to move the can. In other words creating an imbalance of pressure on the cans. The faster the flow of air, the lower the pressure it exerts.

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